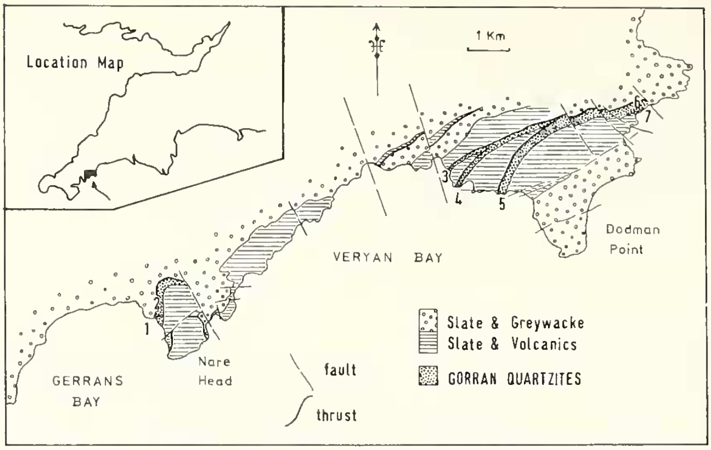
TRILOBITES FROM THE GORRAN QUARTZITES, ORDOVICIAN OF SOUTH CORNWALL

by P. M. SADLER

ABSTRACT. The Llandeilo age of the Gorran Quartzites of south Cornwall and the Armorican affinities of the faunas suggested by some earlier authors are confirmed by a study of existing collections and material from two new localities. Revised descriptions and illustrations are given for species of *Neseuretus* and *Kloucekia* found in the quartzites of Veryan Bay and Gorran Haven. The presence of a species of *Bathycheilus* is recorded from there, with additional trinucleid and ogygiocaridinid material. A new species of *Crozonaspis*, a genus known from the Llandeilo of the Armorican Massif, Spain and Morocco, is described from the quartzites in Gerrans Bay. Since the deformation of the fossils is relatively slight, some primary variation within *Neseuretus* (*N.*) *tristani* seems to be demonstrable.

STRATIGRAPHICAL and structural investigations in Gerrans Bay and Veryan Bay in south Cornwall have indicated the presence there of several features similar to the Palaeozoic geology of the Armorican Massif. They include a confirmation and amplification of the Armorican affinities of the faunas of the Gorran Quartzites, which were first recognized by Salter (1864). A Lower and Middle Devonian sequence (dated by conodont faunas) comprising slate and volcanic rocks succeeded by greywacke appears to rest with non-angular unconformity on the Ordovician Gorran Quartzites. Since thrust faults repeat the succession, at most only about 200 m of the Ordovician part is seen. The Ordovician trilobite-brachiopod faunas were the first reliable indication of stratigraphical age available in south Cornwall (Peach 1841; Murchison 1846). This age was at one time supposed to be applicable to the volcanic succession and much of the greywackes (Reid 1907). Peach (1841, 1842, 1844) discovered the fossils at Carne, Diamond Rock, and Perhaver Beach and recorded the presence of *Calymene* and several orthid brachiopods. Salter (1864, 1865) described species of *Calymene*, *Phacops*, and *Homalonotus* from the Gorran Quartzites for which he proposed Llandeilo (p. 9 of his monograph) and Arenig (pp. 100, 214) ages. He recognized the resemblance of the trilobites to fossils of the 'May' sandstone of Normandy, and that one of the Cornish species also occurred in the derived quartzite clasts of the Triassic Pebble Beds at Budleigh Salterton. Peach's material was redescribed by J. Sowerby (in Murchison 1846, p. 321), M'Coy (in Sedgwick 1852, p. 13) and by Davidson (in Collins 1893). Further material was collected from Perhaver Beach by Mrs. C. Reid during preparation of the Geological Survey, New Series sheet 353 (Reid 1907). These trilobites were determined by Lake (in Reid 1907) who suggested that *Cheirurus* occurred in the faunas, which were probably of Llandeilo age and to be correlated with the Angus Slates or the Grès de May. Stubblefield (1939*a*, 1960) confirmed this probable mid Ordovician date with a revised faunal list for the Gorran Quartzites and the discovery of a trinucleid pygidium in the material from Perhaver Beach. Whittard (1958, p. 115) noted that the specimen referred by Lake to *Cheirurus sedgwicki* more closely resembled *Eccoptochile clavigera*

[Palaeontology, Vol. 17, Part 1, 1974, pp. 71–93, pls. 9–10.]



TEXT-FIG. 1. Generalized geological map of south Cornwall, with outcrop of Gorran Quartzites and fossil localities indicated: 1, Carne Beach; 2, Carne quarries; 3, Diamond Rock; 4, East Catasuent; (5, Black Rock); 6, Perhaver quarry; 7, Perhaver Beach.

(Beyrich), but advised that other fossils from the Perhaver fauna did not support a Llanvirn–Llandeilo age.

Of the major quartzite outcrops, only Black Rock has failed to yield fossils. Diamond Rock (SW 9754 4083) and Perhaver Quarry (SX 0142 4230, rock face no longer available) have each yielded brachiopods and a single trilobite pygidium, while Carne quarries (SW 9127 3820) have yielded brachiopods and the only record of an articulated trilobite thorax and pygidium (Fox 1908). The main Peach and Reid collections are from huge fallen blocks below the quartzite outcrops of Great Perhaver Beach (SX 0174 4234). Recent searches there have produced only poorly preserved material, but it has been possible to collect a similar fauna from a new site, *in situ* immediately east of Catasuent Cove (SW 9765 4076). A different, apparently monospecific, fauna has been collected from a large detached block below the quartzite outcrops of Carne Beach (SW 9109 3793). The Truro city museum contains a typical pygidium of *Basilicus tyrannus* (Murchison), found by C. J. Lane in a sandstone block in the wall of Elerky House, Veryan (SW 9139 3949), but whereas the matrix is unlike the Gorran Quartzites, it closely resembles that of the Llandeilo Flags near Llandeilo itself (pers. comm. A. W. A. Rushton).

The trilobites occur with abundant brachiopods in rare layers as ferruginous moulds, usually concentrated toward the base of laminated, and occasionally cross-laminated, quartz-sand beds. This paper describes some of the trilobites in the earlier collections as well as the author's own material. The brachiopods have been deposited, without detailed determinations, in the collections of the Institute of Geological Sciences, London. The Devonian conodont faunas and the stratigraphy will be treated in later papers. The trilobites identified are:

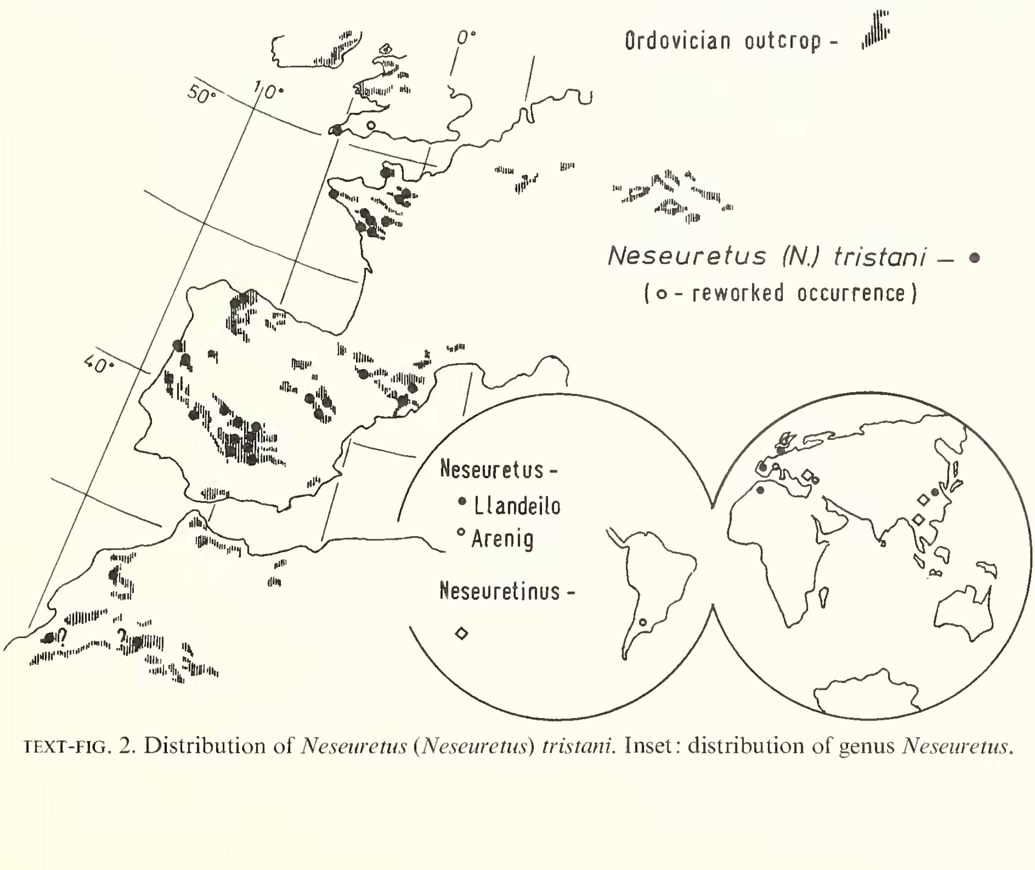
Carne Beach: *Crozonaspis peachi* n. sp.

East Catasuent: *Neseuretus* (*N.*) *tristani* (Brongniart), *Neseuretus* (*N.*) cf. *N. complanatus* Whittard, *Bathycheilus* n. sp. aff. *B. perplexus* (Barrande), *Kloucekia* (*K.*) *mimus* (Salter), Trinucleidae gen. indet., Ogygiocaridinae gen. indet.

Perhaver Beach: *Neseuretus* (*N.*) *tristani* (Brongniart), *Bathycheilus* n. sp. aff. *B. perplexus* (Barrande), *Kloucekia* (*K.*) *minus* (Salter), *Homalonotus* sp., *Eccoptochile clavigera* (Beyrich)? (?Whittard 1958), Trinucleidae gen. indet. (Stubblefield 1939*a*, p. 68), Ogygiocaridinae gen. indet.

Age and Correlation. Since previously described species of *Crozonaspis* (Henry 1968; Clarkson and Henry 1970; Carré *et al.* 1972; Destombes 1972) are confined to the Llandeilo, it is probable that the Carne Beach fauna is also of Llandeilo age. *Neseuretus* (*N.*) *tristani* occurs in the Llanvirn and Llandeilo of Brittany (Nion and Henry 1966, p. 885; Clarkson and Henry 1970, pp. 119–121). It is especially abundant near the Llanvirn–Llandeilo boundary, and again in the upper Llandeilo, but it disappears abruptly before the Caradoc. *Kloucekia* is recorded as beginning in the Llandeilo and extending through the upper Ordovician (Destombes 1972, p. 18), so its association with *N.* (*N.*) *tristani* in the Catasuent and Perhaver faunas again suggests a Llandeilo age. This means that the Gorran Quartzites, originally correlated by Salter (1864) with the 'May' Sandstone of Normandy can now more precisely be correlated with the grès de May inférieur ('Petit May') of Normandy and the grès de Kerarvail and schistes de Morgat of Finistère (Henry 1970, p. 23). In those areas there is a stratigraphic break between the Caradoc or Llandovery below and the Upper Silurian or Lower Devonian above (Renaud *et al.* 1968).

The faunas of the Gorran Quartzites are interesting in the context of the distribution of Ordovician trilobites. They contrast strongly with the contemporaneous Anglo-Welsh faunas which are dominated by trinucleid and asaphid trilobites (Stubblefield 1939*b*, p. 55; Dean, in Whittard 1967, p. 314). An abundance of *Neseuretus* during



TEXT-FIG. 2. Distribution of *Neseuretus* (*Neseuretus*) *tristani*. Inset: distribution of genus *Neseuretus*.

the Arenig characterizes the Welsh area (Whittard 1960; Whittington 1966*a*; Bates 1968, 1969) and the Montagne Noire (Dean 1966), where the genus is unknown above the lower Llanvirn. A Llanvirn–Llandeilo abundance of *Neseuretus*—usually referred to *N.* (*N.*) *tristani*—characterizes Cornwall and the Armorican Massif, Spain, Portugal, and North Africa (Born 1916; Spjeldnaes 1961; Whittington 1966*b*). In the Cornish faunas trinucleid and asaphid trilobites are a minor element only. The genus *Crozonaspis* seems to have had a distribution similar to that of *N.* (*N.*) *tristani*. During Llanvirn times, Anglo-Welsh, German (Rheinisches Schiefergebirge: Siegfried 1969), and Bohemian (Dean, in Whittard 1967, p. 310) trilobite faunas were closely related, but this link was not again clearly in evidence until mid Caradoc time, when *Kloucekia* appeared in Welsh faunas (Dean 1961; Whittington 1962). *Kloucekia* is known from the Llandeilo in Bohemia (Henry 1965, p. 205), during which time it was present in Brittany and Cornwall also. The record of *Bathycheilus* commences in the Arenigian of the Montagne Noire (Dean 1965, 1966) and extends to Bohemia, Portugal (Thadeu 1956), and apparently Cornwall, in the later lower Ordovician. *Bathycheilus* is not known in Brittany, but the related genus *Prionocheilus* is recorded there (Rouault 1847). The presence of *Eccoptochile* in the Perhaver fauna (Whittard 1958, p. 115) provides further indication of Bohemian affinity. The possibility of a link between the Welsh and Armorican Massif faunas exists in the highest Llandeilo when *Marrolithus* occurs in both areas (Stubblefield 1939*b*, p. 54). This is apparently the earliest appearance of Trinucleidae in the Armorican region (Oehlert 1895; Nion and Henry 1966).

Pebbles of Ordovician Quartzites of similar appearance to the Gorran Quartzites and the grès de May and grès de Kerarvail occur in the Triassic (Warrington 1971, p. 312) Budleigh Salterton Pebble Beds, and *Crozonaspis* (Henry, in Carré *et al.* 1972, p. 781) and *Neseuretus* (*N.*) *tristani* (Salter 1864) have been found.

SYSTEMATIC DESCRIPTIONS

All the specimens treated here are deposited in the collection of the Institute of Geological Sciences, London (GSM). Suffixed letters distinguish particular moulds on a single numbered block. All descriptive terminology is from the Treatise (Moore 1959) unless otherwise stated. The use of open nomenclature and annotated synonymy lists follows the scheme proposed by R. Richter (1948).

Family ASAPHIDAE Burmeister, 1843
Subfamily OGYGIOCARIDINAE Raymond, 1937
Genus and species indet.

Plate 10, figs. 1–2

Material. East Catasuent—1 librigena and 2 incomplete pygidia. Perhaver Beach—2 pygidia, coll. Reid 1907 (GSM CR 1545–1548 and 1498).

Remarks. Rare, large fragments which occur are not considered adequate for generic recognition, since generic differences in this subfamily are rather subtle and in some respects controversial. The pygidia are of two types. One (Pl. 10, fig. 2) from East Catasuent resembles *Ogygiocarella* Harrington and Leanza 1957. The pleural lobes bear deep asymmetrical interpleural furrows, near the distal ends of which there are faint, divergent pleural furrows developed on the anterior part of the pleura. The wide border, which has no furrow, bears very slight trace of concentric striation. The second type (not illustrated) resembles *Ogygiocaris* Brünnich 1781 and has been found at East Catasuent (GSM Zs 589) and Perhaver Beach. These pygidia are semicircular, with a narrow, tapering, feebly segmented axis which terminates against a wide, smooth border. The pleural lobes bear faint furrows adaxially.

Family TRINUCLEIDAE Hawle and Corda, 1847
Genus and species indet.

Plate 10, figs. 3–5

Material. East Catasuent—7 cephala. Perhaver Beach—1 pygidium (Stubblefield 1939*a*, p. 68).

Description. Cephalon with semicircular outline, about two-thirds as long as broad, except for Pl. 10, fig. 5 which is only one-third as long as broad but probably compressed axially. (The available material is insufficient and too dispersed for a proper assessment of the contribution of tectonic deformation, but this individual could be a W-form (Henningsmoen 1960, p. 207) in a strained domain with a shortening of at least 1:0·75.) Pear-shaped glabella with three, paired, lateral furrows arranged as in *Trinucleus* Murchison 1839. 1p and 2p lateral furrows short, deep, triangular notches separated by a narrow (exsag.) rectangular 2p lobe, which is not isolated. 3p furrows very short, inconspicuous indentations. Swollen frontal glabellar lobe continuous with 3p lobes, high and rounded, but does not overhang or transgress on to anterior fringe. Median glabellar tubercle (Whittington 1968, p. 703) sited between 3p furrows. Axial furrows very deep, narrowing and diverging forward. Occipital furrow shallow, curved, convex backward. Occipital ring narrow (sag.), without spine. Cheek lobes convex, quadrant shaped, less elevated than glabella. Lateral margins fall steeply to fringe. Abaxial posterior corner of cheek lobes pointed and directed backward to constrict posterior border furrow.

Eye-tubercles a little away from brink of axial furrows, opposite (tr.) median glabellar tubercle (Pl. 10, fig. 4). Posterior border furrow wide, abruptly constricted abaxially at a point beyond widest and deepest portion. Posterior border a low ridge.

Pitted fringe (insufficiently complete for generic determination) appears to be narrow (1 mm in GSM Zs 577), comprising at least three arcs anteriorly, and is apparently unexpanded at the anterolateral angle. Only the innermost arc is satisfactorily seen showing at least fifteen pits in the half-arc; it seems to comprise the largest and deepest pits and is not transgressed by the frontal glabellar lobe.

Family SYNHOMALONOTIDAE Kobayashi, 1960
Genus NESEURETUS Hicks, 1872

Type species. Neseuretus ramseyensis Hicks, 1872. Subsequent designation by Vogdes (1925, p. 106).

Whittard (1960, pp. 138–139) has argued that *Synhomalonotus* Pompeckj 1898 is a junior subjective synonym of *Neseuretus* Hicks and has given a diagnosis for the genus. This account accepts both Whittard's diagnosis and his view of the status of *Synhomalonotus*. Whittard (1960, p. 140) designated *N. murchisoni* (Salter) as the type species—i.e. *Calymene parvifrons* var. *murchisoni* Salter, which is not synonymous with *N. parvifrons* as Bates (1969, p. 22) implies—believing it to be a senior synonym of *N. ramseyensis*. However, Bates (1969) has shown that they are not conspecific. Bates did not, unfortunately, specify the difference between *N. ramseyensis* and *N. tristani* (Brongniart), the type species proposed for *Synhomalonotus* by Pompeckj (1898), which is regrettable since the two are apparently to be distinguished from *N. murchisoni* by the same criteria—compare Whittard 1960, p. 149, and Bates 1969, p. 25.

Sdzuy (1957, p. 277) has argued that *Neseuretus* (= *Synhomalonotus*) should be transferred from the Calymenidae Milne-Edwards 1840 (where it was placed by, among others, Shirley 1936, p. 394) to the Homalonotidae Chapman 1890, because of the form of the glabella and anterior area (Whittard 1960, p. 143, for definition of anterior area). Sdzuy's practice, which acknowledges the similarity between *Neseuretus* and *Calymenella*, was followed by Bates (1968, 1969). On ventral morphologies, Whittington (1966*a*) considered *Neseuretus* to be a calymenid which had an anomalous hypostome associated with the relatively long preglabellar field, a proposal accepted by Henry (1970). Whittington (1966*a*) and Whittard (1960), who also placed *Neseuretus* in the Calymenidae, nevertheless considered that *Neseuretus* must belong to a stock from which the later calymenids and homalonotids were derived but not precisely referable to either family. A separate family is preferred here, following Dean (1966, p. 297; 1971, p. 9).

Stratigraphical range. Arenig and Lower Llanvirn of Wales (Whittington 1966*a*; Bates 1968, 1969) and the Welsh Borderland (Whittard 1960), and the Arenig of the Montagne Noire (Dean 1966) and Turkey (Dean 1971). Widespread in Llanvirn and Llandeilo of Brittany (Henry 1970), the Iberian peninsula (Born 1916), and North Africa. Also recorded in Burma, central and west China (Reed 1915; Kobayashi 1951; Lu 1957), and Argentina (Harrington and Leanza 1957). Not recorded from the Ordovician of Bohemia, Scandinavia, or North America (text-fig. 2). No Caradoc record.

Remarks. The longer anterior area of *Neseuretus* distinguishes it from *Platycalymene* (Llanvirn–Caradoc) and *Flexicalymene* (Llandeilo–Ashgill). *Calymenella* may closely resemble *Neseuretus* in the form of its anterior area and may also develop faint oblique eye ridges, but it has less distinct glabellar furrows. The two genera have very similar pygidial segmentation, but the last axial ring of *Calymenella* does not reach the posterior margin of the pygidium. Although Arenig occurrences of *Neseuretus* have been divided into several well-defined species, with emphasis on the form of the anterior area, almost all Llandeilo occurrences of the genus in Europe (and they are rather variable) appear to have been indiscriminately assigned to the inadequately defined species *N. tristani* (Brongniart).

Subgenus NESEURETUS (NESEURETUS) Hicks, 1872

Dean (1967) has proposed two subgenera. *N.* (*Neseuretinus*) Dean differs from the nominate subgenus by a distinctly convex preglabellar field between an enlarged and arched anterior border and the frontal glabellar lobe. Apart from *N. birmanicus* Reed all species described prior to 1967 belong to *N.* (*Neseuretus*).

Neseuretus (*Neseuretus*) *tristani* (Brongniart, 1822)

Plate 9, figs. 4–12; text-fig. 3

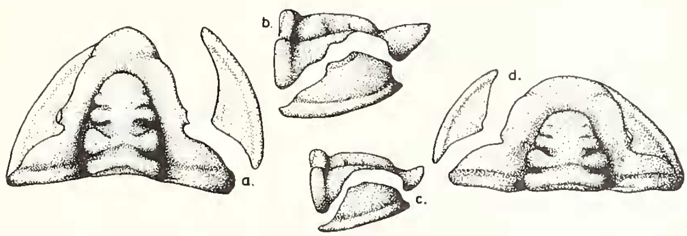
1808 Tristan and Bigot, p. 21.
*1822 *Calymene Tristani* Brongniart, pp. 12–14, pl. I, fig. 2F–I, *non* 2A–E (= *Colpocoryphe aragoi* (Roualult)), ?*non* 2K.
v?*1846* *Calymene pulchella*; Sowerby *in* Murchison, p. 231.
v?*1852* *Calymene parvifrons* Salter? (?M'Coy); M'Coy *in* Sedgwick, p. 13.
v1864*a* *Calymene Tristani* Brongniart; Salter, p. 291, pl. 15, fig. 5.
v1864 *Calymene Tristani* Brongniart; Salter, pp. 99–100, pl. 9, figs. 15–18.

v?*1893* *Calymene parvifrons* Salter; Collins, p. 470.
v?*1893* *Calymene Tristani* Brongniart; Collins, p. 471.
v*1907* *Calymene Tristani* Brongniart; Lake *in* Reid, p. 39.
v*1939a* *Synhomalonotus*; Stubblefield, p. 68.
v*1960* *Neseuretus*; Stubblefield, p. 102.
1970 *Neseuretus* (*Neseuretus*) *tristani* (Brongniart); Henry, pp. 5–11, pl. A, figs. 1–10.

Type specimens. Brongniart's specimens appear to be lost, and Henry (1970) has selected and figured a neotype from Hunaudière, the type locality.

Material. East Catasuent—48 cranidia (including 17 representatives of variant two, 23 of variant three, 1 of ?variant one, 7 very incomplete), 10 librigenae, and 19 pygidia. Perhaver Beach—abundant disarticulated material in Reid collection.

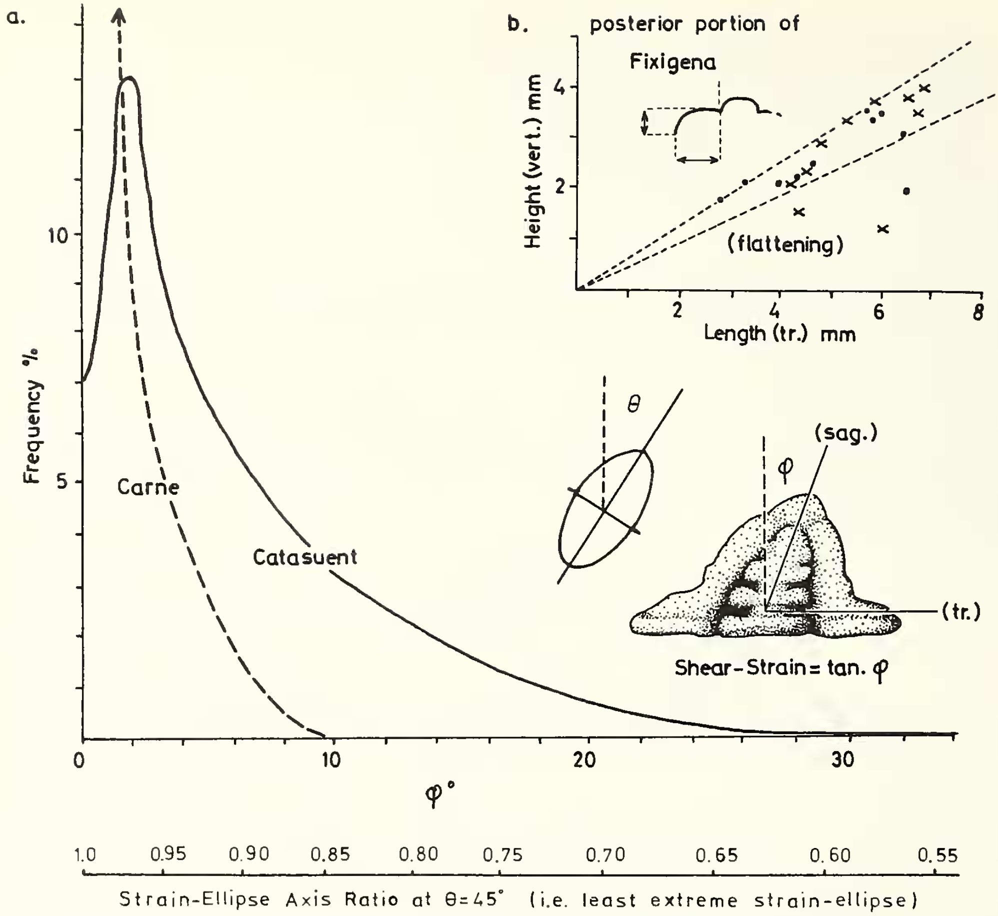
Diagnosis. A species of *Neseuretus* (*N.*) characterized by a pronounced, arched (sag.) anterior area which, in longitudinal profile, slopes distinctly and continuously downward and backward to the preglabellar furrow (text-fig. 6). The anterior area may or may not possess a weak anterior border furrow. The posterior and median lateral glabellar furrows are distinct and wide (exsag.), but the anterior lateral glabellar furrow may be very inconspicuous. In longitudinal profile the glabella is moderately convex, sloping gently to the preglabellar furrow.



TEXT-FIG. 3. Reconstruction of *Neseuretus* (*Neseuretus*) *tristani*. *a–b*, variant 2 based on Zs 590a; *c–d*, variant 3 based on Zs 609a. ×1·7.

Description. Both Brongniart (1822, p. 13) and Henry (1970, p. 11) mention the varied nature of the anterior area in *N.* (*N.*) *tristani*, attributing this partly to compaction and deformation. However, some of the differences among previously figured specimens—such as the presence or absence of an anterior border furrow—are probably primary. Henry notes that in Brittany individuals from siliceous nodules in the slates are almost undeformed and do not show much variation. The material from the Cornish Quartzites is little deformed. Flattening is rarely evident, even in the especially vulnerable, long and very convex (tr.) posterior areas of the fixigenae, and angular shear strain is usually low and its effects obvious (text-fig. 4). Occasionally the anterior area is crushed backward on to the glabella but the accommodating fractures in the exoskeleton are clearly preserved on the moulds (Pl. 9, fig. 8). Examination of the Cornish material shows three variants among cranidia of *N.* (*N.*) *tristani*:

Variant one (?Pl. 9, fig. 8). Brongniart's (1822, Pl. 1, fig. 2G) illustration of one of the syntypes shows an anterior border furrow and a relatively short, strongly convex glabella. Only one individual from Cornwall has an anterior border furrow. This furrow is present in individuals from Spain (Born 1916, pl. 26, figs. 4*b*–*c*; 1953, pl. 7, figs. 3–4) and is weakly developed in rather squat, strongly convex cephalic shields from Brittany (Henry 1970, text-fig. 1, pl. A, figs. 1–3). Whittard (1960, p. 145) regarded the presence of an anterior border furrow as essential to *N.* (*N.*) *tristani*, and variant one, which includes both one of the syntypes and the neotype, could be regarded as *N.* (*N.*) *tristani* sensu stricto. A marked anterior border furrow and an approximately square, very convex glabella are found in *N.* (*N.*) *murchisoni*, but in the latter superficially similar species part of the anterior area slopes forward (text-fig. 6). With one exception, the Cornish specimens examined lack an anterior border furrow. They would therefore meet the specification of Whittard's (1960, p. 145) working definition of *N.* (*N.*) *parvifrons*, but are placed under *N.* (*N.*) *tristani* here because of the slope of the anterior area. Subjectively, the material can readily be cast into two groups



TEXT-FIG. 4. Shear strain and flattening in the Gorran Quartzite faunas. *a*, shear strain in total faunas from Carne and Catasuent; *b*, flattening in *N.* (*N.*) *tristani* from East Catasuent, dots variant 2, crosses variant 3.

EXPLANATION OF PLATE 9

All specimens dusted with ammonium chloride. Indian ink backgrounds have been added.

Bathycheilus n. sp. aff. *perplexus* (Barrande).

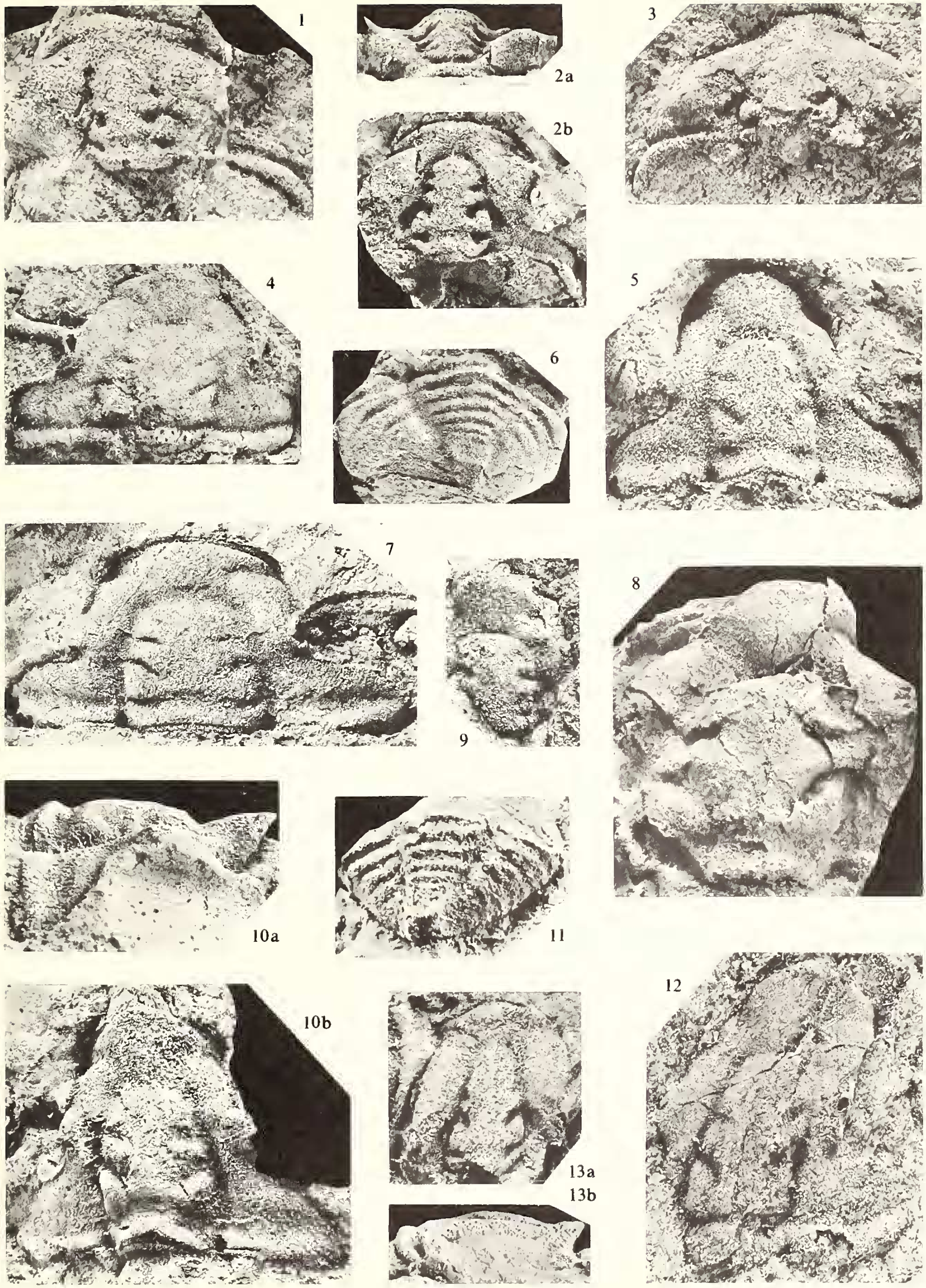
Fig. 1. GSM CR 19599, cranidium, latex cast from external mould, Perhaver, ×3·5. Fig. 2*a–b*. GSM Zs 609d, cranidium, internal mould, Catasuent, ×3. *a*, frontal view, showing right palpebral lobe; *b*, dorsal view. Fig. 3. GSM CR 1556, cranidium, showing left paraglabellar area, latex cast from external mould, Perhaver, ×3·5.

Neseuretus (*Neseuretus*) *tristani* (Brongniart), all from Catasuent.

Fig. 4. GSM Zs 609b, var. 3 cranidium, latex cast from external mould (pits in occipital ring are flaws in cast), ×3·5. Fig. 5. GSM Zs 611a, var. 2 cranidium, internal mould, showing anterior pits and occipital apodemes, ×3·5. Fig. 6. GSM Zs 631, pygidium, ×3. Fig. 7. GSM Zs 609a, var. 3 cranidium, internal mould, ×3. Fig. 8. GSM Zs 614, ?var. 1, large crushed cranidium (note fractures and telescoped preglabellar furrow), internal mould, ×3·5. Fig. 9. GSM Zs 613, glabella and anterior area, latex cast from external mould, ×3. Fig. 10*a–b*. GSM Zs 590a, var. 2 cranidium, internal mould, ×3·5. Fig. 11. GSM Zs 632, pygidium, ×3. Fig. 12. GSM Zs 609c, var. 2 cranidium, latex cast from external mould, ×3·5.

Neseuretus (*Neseuretus*) cf. *complanatus* Whittard.

Fig. 13*a–b*. GSM Zs 590b, cranidium, internal mould, Catasuent, ×3·5. *a*, dorsal view; *b*, slightly oblique lateral view.

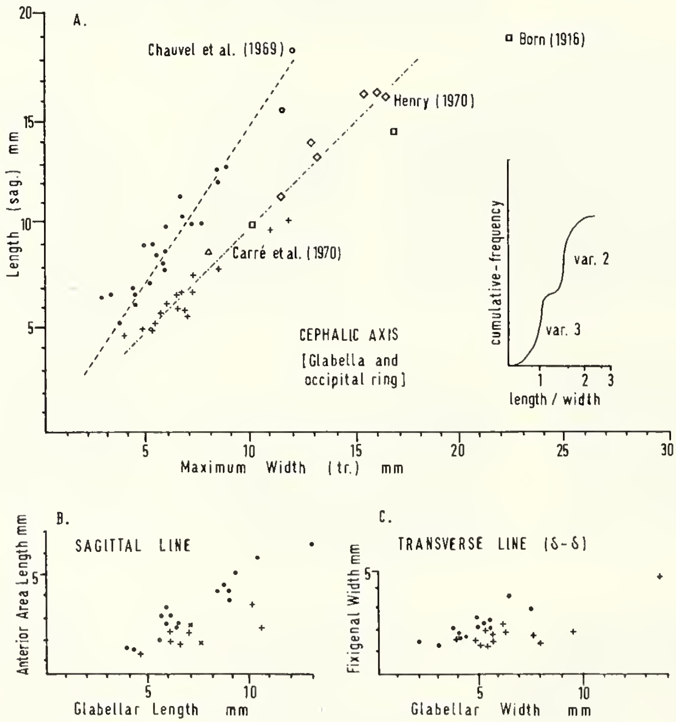


SADLER, Cornish Ordovician trilobites

according to the shape of the glabella and anterior area, and measurement seems to confirm the existence of two discrete types (text-fig. 5); these are here termed variants two and three.

Variant two (Pl. 9, figs. 5, 10, 12) is the slimmer of the two types that dominate the Cornish material and may also include similar material from Spain (Chauvel *et al.* 1969, pl. 4, figs. 1, 1*a*).

Cranidium sub-triangular, about two-thirds as long as broad and strongly convex transversely. Posterior edge nearly straight but rounded genal angles may project slightly backward. Gonatoparian. Glabella sub-rectangular, longer than wide, limited by broad, conspicuous axial furrows, approximately parallel from occipital ring to 2p lobe, then converging forward at about 30°. Three pairs of glabellar furrows. 1p furrows short, deep, wide (exsag.), increasing in width adaxially and curved or angled backward at about 50° from junction with axial furrows. 2p furrows broad (exsag.), shallower, very slightly oblique, also intersect axial furrows. 3p furrows barely perceptible. 1p lobes convex and axe-shaped. 2p lobes flatter, widen slightly toward axis. 3p and frontal lobes rarely separable, truncate outline. Fossulae shallow. Central area of glabella fairly flat. Occipital furrow broadest (sag.) and shallowest axially; deep pits in the axial furrows adjacent to the occipital ring of internal moulds (Pl. 1, figs. 5, 10*b*) are not seen on external casts and represent ventral articulating bosses or apodemes without external expression. A large anterior area lies between two shallow, divergent, arcuate anterior furrows (Whittard 1960, p. 139) which curve outward through more than 90°. Anterior area flat to very gently convex, sloping distinctly and gently backward to preglabellar furrow. Anterior margin unfurrowed, moderately tightly curved to slightly pointed and inclined at 50–60° to horizontal in side view. Fixigenae narrow (tr.) adjacent to glabella, extend posteriorly as markedly down-



TEXT-FIG. 5. Differentiation of *N.* (*N.*) *tristani* variant 2 and variant 3 according to shape: dots = variant 2, crosses = variant 3, open symbols = previously figured examples. A, shape of cephalic axis, uncorrected for deformation, inset replots Cornish data as a cumulative frequency; B and C, ratios from a single line, independent of deformation. B—along sagittal line, C—along transverse line through midpoints of palpebral lobes.

curved wings with distinct, broad, posterior furrows. Eyes opposite 2p lobes, with narrow (tr.) palpebral lobes. Eye ridges barely perceptible. Visual surface of eyes unknown.

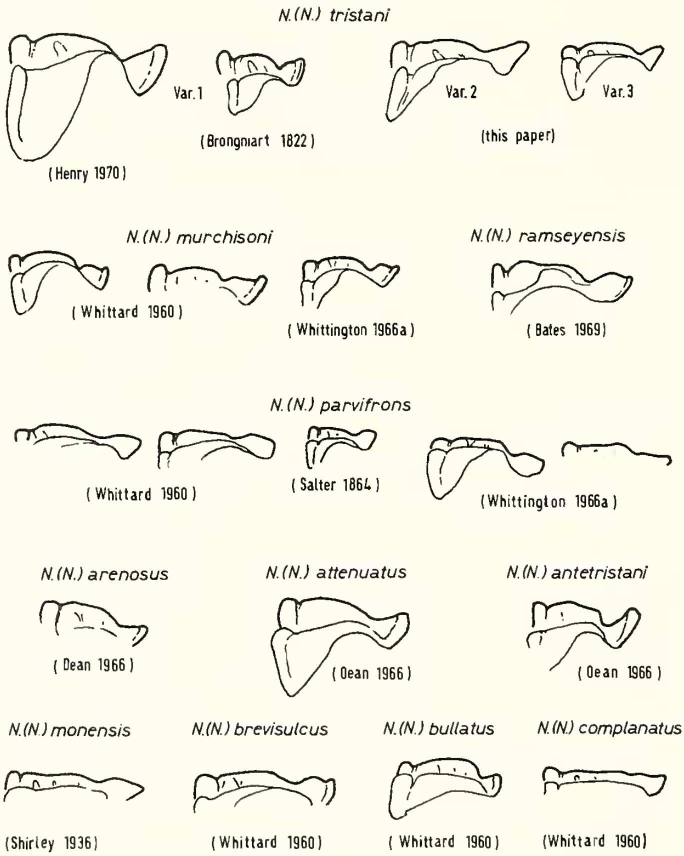
Variant three (Pl. 9, figs. 4, 7). Cranidium relatively short, only half as long as broad, strongly convex transversely (text-fig. 4*b*). Posterior margin approximately straight but posterior portion of fixigenae may be directed slightly forward. Gonatoparian. Cephalic axis (glabella with occipital ring) almost square; broad axial furrows converge at 30–40° in front of 1p furrow. Three paired glabellar furrows positioned as in variant two, but narrower, more sharply incised. 3p furrows rarely seen. Glabellar lobes tend to be flatter. The furrows are similar to *Calymenella* (Sdzuy 1957, pl. 1, figs. 2, 5) but much more distinct. Glabellar axis somewhat more convex (sag.) than in variant two. Pits adjacent to occipital ring in internal moulds only. Wider anterior area lies between weak, rapidly divergent anterior furrows. Anterior area profile (sag.) more convex, shorter than in variant two, but without forward sloping regions such as are seen in *N.* (*N.*) *parvifrons* and *N.* (*N.*) *monensis*. Anterior margin unfurrowed, describing a very flat curve and inclined at 70–80° to horizontal in side view. Shallow semicircular depressions adjacent to 1p lobes but no distinct paraglabellar lobes.

Since the curvature (tr.) of the convex posterior margin shows the same range of variation in variants two and three (text-fig. 4) the latter variant can scarcely be the result of flattening of the former. Although a few individuals show some intermediate character (e.g. Pl. 9, fig. 5—variant two proportions with rather narrow (exsag.) glabellar furrows) measurement of glabellar proportions indicates that in the available Cornish material no continuous variation exists between variants two and three (text-fig. 5). Since the moulds have no preferred orientation on the bedding planes, the frequency distribution of angular shear strain (text-fig. 4) indicates that strain is variable but usually only slight. These low shear strain values and the distinct lack of intermediate shapes, whether in symmetrical or asymmetrical individuals, suggests that variants two and three are not simply L- and W-forms (Henningsmoen 1960, p. 207) produced from a single original shape by transverse and sagittal compression respectively. If variant three had been produced by sagittal compression it ought to show consistently less transverse convexity than forms generated by transverse compression and possess relatively accentuated glabellar lobes. Neither criterion is met by the Cornish material. A single block (GSM Zs 609) bearing eleven cranidia (including Pl. 9, figs. 2, 4, 7, and 12) on a 25 sq cm bedding plane offers the best means of assessing the significance of L- and W-forms. Three variant three individuals (including Pl. 9, figs. 4 and 7) occur in immediate juxtaposition, with their axial directions at angles of 88° and 59° to one another, while a distinct variant two cranidium (Pl. 9, fig. 12) lies with its transverse direction divergent from that of one of the former by only 21°. L- and W-forms should be oriented at approximately right angles to one another in regions of homogeneous strain. Using Wellman's method (1962) the best-fit strain ellipse for this bedding surface has an axial ratio of 1:0·92. A strain ratio of 1:0·58 produces typical symmetrical examples of variants two and three (Pl. 9, figs. 10 and 7) from a single O-form, and a strain ratio exceeding 1:0·81 is necessary to generate the mean values of glabellar shape for oblique or asymmetrical variant two and three forms, even if at right angles to one another. The strain is not fully homogeneous even over this small area. The Wellman diagram shows that one variant two individual (Pl. 9, fig. 12) accommodates an anomalously high strain which can be calculated as an ellipse axis ratio of 1:0·78. However, to produce this individual and the nearest variant two from a common O-form requires a strain ratio more extreme than 1:0·56 (the theoretical value for equivalent perpendicular shapes). Primary variation is also indicated by ratios of parallel lengths which should be unaltered by deformation but show consistent differences between variants two and three. Variant two has consistently larger ratios of fixigena width to glabellar width (opposite 2p furrows) and anterior area length (sag.) to glabellar length (text-fig. 5B and C). Apart from the possibility of locally very inhomogeneous strain, these lines of evidence indicate that variants two and three, although superficially compatible with the products of tectonic deformation, are based on a primary, discontinuous variation. Specimens figured by Chauvel *et al.* (1969) are larger, but plot unambiguously with variant two (text-fig. 5). However, previously illustrated material with an anterior border furrow (listed above as variant one) plots close to variant three, and Henry's (1970) material seems to indicate that continuous variation may exist between variants one and three. Further study of relatively undeformed material may show that variant two deserves formal separation from *N.* (*N.*) *tristani* sensu stricto.

Librigenae. Only disarticulated examples found. Convex, triangular. Upturned flange at apex bordering eye. Broad lateral border furrow and pronounced raised lateral border which extends into rounded genal angle. If placed in apposition to facial suture librigena would be steeply inclined to horizontal.

Pygidia. Small, triangular, about twice as wide as long. Deep axial furrows. Marked anterolateral bevels on pleural field, tapering backward. Posterior margin chevron-shaped. Segmentation less distinct toward posterior, up to ten axial rings distinguishable. Five to six pleural furrows. Shallow pleural furrows at distal ends of pleura.

Remarks. Although there may be close resemblance to *N.* (*N.*) *murchisoni* or *N.* (*N.*) *parvifrons*, *N.* (*N.*) *tristani* can be separated from these and most other species, as Henry (1970) has shown, by the rearward sloping profile (sag.) of the anterior area (text-fig. 6). In *N.* (*N.*) *antetristani* Dean 1966 the glabellar furrows are much less distinct and the relatively narrow frontal lobe falls abruptly to the preglabellar furrow.



TEXT-FIG. 6. Comparison of longitudinal cephalic profiles within the subgenus *Neseuretus* (*Neseuretus*).

Distribution. (Text-fig. 2.) *N.* (*N.*) *tristani* is common in the Llanvirn and Llandeilo of Normandy and Brittany, the Pyrenees, Portugal, Spain, and Morocco. It is absent from the Llanvirn and Llandeilo of Wales and the Welsh Borderland, although the genus is well represented in the Arenig there. Its appearance in the Llanvirn of Brittany is rather abrupt. This may relate to the coincident rapid transition from the quartzites of the Grès Armorican to the Courijou or Kerloc'h slates. *N.* (*N.*) *tristani* has been recorded from derived quartzites in the Budleigh Salterton Pebble Beds (Salter 1864*a*).

Neseuretus (*Neseuretus*) cf. *N. complanatus* Whittard, 1960

Plate 9, figs. 13*a–b*

Material. East Catasuent—1 incomplete cranidium.

Description. Narrow, conspicuously tapering glabella, limited by axial furrows converging at 25°. Occipital furrow deep adjacent to axial furrows, crossing axis as a shallow trough. 1p furrows short and deep, angled backward, defining axe-shaped 1p lobes. 2p furrows shallower and very short. 3p furrows not present. Preglabellar furrow faint, with very shallow fossulae. Glabellar profile (sag.) very low, only slightly higher than anterior portions of fixigenae, which are long, inflated, and relatively wide. Posterior portions of fixigenae not seen. Anterior portion of sutures fairly straight, only slightly convergent forwards. Anterior area about one-third glabellar length, slightly lower than glabella and slightly convex. Anterior margin a flat curve.

Discussion. Whittard (1960, p. 147) erected the species *N. complanatus* to accommodate two cranidia from the Mytton Flags fauna (Arenigian, Shelve inlier) which had an unusually flat profile (sag.), a narrow glabella without 3p furrows, and inflated, wide (tr.), parallel-sided anterior portions of the fixigenae. The incomplete cranidium (described above) incorporates comparable features, but lacks the somewhat elongate anterior area of the holotype, and has a more pointed frontal lobe. The species has nowhere been recorded in large numbers.

Family BATHYCHEILIDAE Přibyl, 1953

Diagnosis. An emended diagnosis for this family, to include two genera—*Bathycheilus* Holub and *Prionocheilus* Rouault (= *Pharostoma*, see Dean 1964)—is given by Dean (1965, p. 1).

Genus BATHYCHEILUS Holub, 1908

Type-species. Dalmanites perplexus Barrande 1872. By original designation.

Diagnosis. Semicircular cephalic outline. Pronounced anterior border. Anteriorly tapering glabella with three pairs of furrows and lobes which diminish in size forward. Distinct paraglabellar areas. Strongly convex anterior portions of fixigenae exceed frontal lobe in height and extend farther forward. Posterior margin of cephalon concave backward. Pronounced posterior border. Opisthoparian. Librigenal spines.

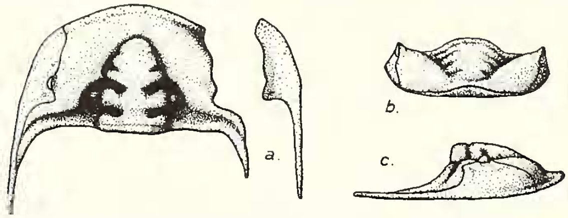
Distribution. Arenig of Montagne Noire (Dean 1965, 1966), Llanvirn of Bohemia (Barrande 1872; Holub 1908), Llanvirn or Llandeilo of Portugal (Thadeu 1956) and possibly Morocco (Gigout 1951).

Bathycheilus n. sp. aff. *B. perplexus* (Barrande, 1872)

Plate 9, figs. 1–3; text-fig. 7

Material. East Catasuent—14 cranidia, 4 librigenae, 1 pygidium (very tentatively associated). Perhaver Beach—7 cranidia in Reid collection.

Description. Cephalon sub-semicircular, frontal margin describing a shallow curve. Maximum width twice median length. Narrow glabella comprises about two-thirds cephalic length (sag.) and one-third maximum width (across occipital ring). Glabellar margins converge forward at 30–40°. Three pairs of short glabellar lobes and furrows leaving a smooth central area. 1p furrows deep and broad (exsag.), curving inward and backward to delimit an anterolaterally rounded 1p lobe which increases in size abaxially. 2p furrows short, deep, and very slightly oblique. 3p furrows are very short, straight notches. Frontal lobe short and steeply rounded. Occipital furrow deeply notched laterally, continuing across axis as a shallow, slightly curved trough. Occipital ring slightly sinuous, parallel-sided except at posterolateral extremities where, in internal moulds, ring narrows to accommodate tear-shaped apodemal pits (Pl. 9, fig. 2*b*). Axial furrows are broad anteriorly but narrow adjacent to 2p lobes. Adjacent to 1p lobes, axial furrows widen markedly toward the posterior border furrow, producing depressed triangular areas in which a small, sub-circular paraglabellar lobe is situated (Pl. 9, fig. 3). Small, low, gently concave preglabellar field with upturned anterior border continuing anterolaterally as a rim. Fixigenae include a 'buttress'-like structure adjacent to the 2p lobe.



TEXT-FIG. 7. Reconstruction of cephalon of *Bathycheilus* n. sp. aff. *B. perplexus*. *a*, dorsal; *b*, frontal; *c*, lateral. Approx. ×2·3.

Their anterior portions are conspicuously inflated, exceeding the glabella in height anteriorly and extending forwards beyond the frontal lobe. Palpebral lobes sited well back, immediately behind 1p furrows, and stand up sharply from the cheek surface (Pl. 9, fig. 2*a*). Visual surface not known. Posterior portions of fixigenae narrow (exsag.), having a pronounced border and curving markedly rearward.

Suture opisthoparian, intersects posterior margin just inside genal angle, runs abaxially from close behind palpebral lobes. Librigenae relatively narrow (tr.) bearing long genal spines. Slight flange below eye.

Hypostome and thorax not known. Pygidium (very tentatively associated) approximately as long as wide. Ten axial rings and tail-piece. Pleural lobes declined abaxially with six furrows.

Discussion. The general style of the cranidium is very similar to *B. perplexus* (refigured by Dean 1965, pl. I). The segmentation of the glabella, development of paraglabellar areas, and the inflation of the fixigenae are closely comparable and the two species present almost identical frontal aspects (compare Pl. 9, fig. 2*a* with Dean 1965, pl. I, fig. 5). However, the Cornish species has a distinctly narrower glabella with a less blunt frontal lobe. Their anterior borders are similar but in *B. perplexus* the preglabellar field is shorter (sag.). The full length of the genal spines of the Cornish species is not seen, but they are probably shorter and certainly less stout. In *B. gallicus* Dean 1965, the anterior portions of the axial furrows are more deeply incised and the anterior margin distinctly arched. The related genus *Prionocheilus* has a characteristic posterior constriction of the axial furrows behind the paraglabellar areas, and its less stout librigenal spines carry a row of short spines on their undersides.

Family DALMANITIDAE Vogdes, 1890
Subfamily KLOUCEKIINAE Destombes, 1972
Genus KLOUCEKIA Delo, 1935

Type-species. *Phacops phillipsi* Barrande. Designation by Delo (1935, p. 408).

Discussion. Destombes (1972, p. 56) supplies a diagnosis of the genus and a discussion of its taxonomic position. Following Dean (1961, p. 321) two subgenera are recognized. *Kloucekia* (*Phacopidina*) is distinguished from the nominate subgenus by its mucronate pygidium. The Cornish material confirms the opinion of Whittington (1962, p. 7) and Dean (1961, p. 321) that small fixigenal spines occur at a subspecific level of variation.

Subgenus KLOUCEKIA (KLOUCEKIA) Delo, 1935
Kloucekia (*Kloucekia*) *mimus* (Salter, 1864)

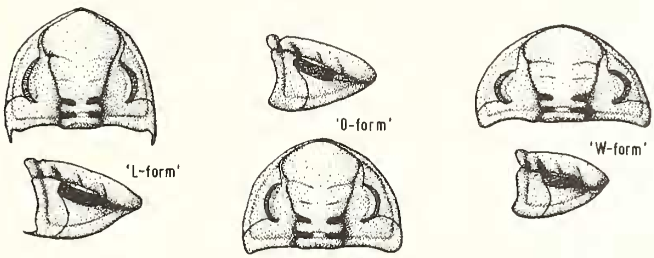
Plate 10, figs. 6–10; text-fig. 8

v*1864 *Phacops* (*Acaste*) *mimus* Salter, pp. 29–30, pl. I, fig. 35.
v*1893* *Phacops mimus* Salter; Collins, p. 472.
v*1907* *Phacops mimus* Salter; Lake (in Reid 1907, p. 39).
v*1960* *Phacops mimus* Salter; Whittard, p. 131.

Lectotype. (Here chosen.) GSM 19180. Cephalon, Perhaver Beach (Pl. 10, fig. 9). Salter's (1864, pl. 1, fig. 35) illustration shows a broken anterior margin and frontal lobe but reconstructs the right eye, which is missing from the specimen itself.

Material. East Catasuent—11 cephala, 18 cranidia, 1 librigena, 5 pygidia. Perhaver Beach—6 cephala (earlier collections).

Diagnosis. A species of *Kloucekia* characterized by a cephalon with large, weakly curved eyes set close to the elongate glabella. Axial furrows slightly divergent anteriorly.



TEXT-FIG. 8. Reconstruction of *Kloucekia* (*K.*) *mimus*. ('L-form' produced by transverse compression, based on GSM Zs 608b (unfigured form with short fixigenal spines); 'W-form' produced by sagittal compression, based on 608c (unfigured form preserved at right angles to 608b); 'O-form' constructed from 608b and c using a calculated strain ellipse axis ratio 1:894. All at ×2·7.

Description. Cephalic outline sub-semicircular, length about two-thirds maximum width (across occipital furrow), anterior margin rounded or bluntly pointed. Rather elongate, pentagonal glabella, maximum width (across frontal lobe) about three-quarters length. Bluntly pointed in front. Axial furrows almost straight, diverging at 20–30°, or curving apart slightly in front of 2p lobe. Three pairs of glabellar furrows and lobes. 1p furrows straight, deep, one-third glabellar width, directed very slightly rearward. 2p furrows very short, straight, very shallow, not reaching axial furrows, 3p furrows longest, shallow, and running almost straight and distinctly rearward from axial furrows. Glabella gently convex and in profile slopes down continuously from occipital ring to anterior border, becoming progressively less convex (tr.) anteriorly. No preglabellar field. Occipital furrow deeply notched laterally, curved forward and shallow medially. Fixigenae carry deep posterior and posterolateral border furrows. Posterior border widens conspicuously toward fixigenal angle, which is usually rounded. One individual (text-fig. 8) bears short fixigenal spines. Eyes narrow and weakly curved, seen in plan view as shallow crescents, extending from immediately posterior of 1p furrow to 3p furrow. Eyes set close to axial furrows anteriorly, with distinct but narrow palpebral lobes. Palpebral area of fixigenae narrow (tr.). Schizochroal visual surfaces with at least twenty-five dorso-ventral files (Clarkson 1966, p. 3) of up to eight hexagonal facets. Posterior sections of facial sutures convex forward, running from rear ends of eyes to lateral margin, with point ω (Richter and Richter 1940, pp. 16–17) slightly behind point ϵ, opposite 1p lobes. Anterior sections skirt closely around frontal glabellar lobe to anterior margin. Small, steeply angled fixigenae with conspicuous antero-lateral furrow.

Hypostoma and thorax not known. Pygidia (tentatively associated) have no caudal spine.

Dimensions. Lectotype: length of glabella (sag.) with occipital ring (Gn) = approx. 5·7 mm (anterior margin reconstructed); width (tr.) of frontal lobe = 4·1 mm; length (exsag.) of eye (A) = 2·1 mm; width (tr.) of occipital ring = 2·7 mm; length of posterior border = 4·1 mm.

Cephalon GSM Zs 600 (an L-form): Gn = 8·1 mm; length of glabella (sag.) without occipital ring (G) = 6·6 mm; length of frontal lobe = 3·2 mm; width of frontal lobe = 5·0 mm; distance between eye and posterior border furrow = 1·1 mm; A = 3·0 mm; width of eye crescent = 1·5 mm; A/G = 45·5%; A/Gn = 37%; width of occipital ring = 2·8 mm; width of fixigena (max.) = 4·3 mm.

Cephalon Zs 597 (a W-form): Gn = 4·5 mm; G = 4·0 mm; length of frontal lobe = 1·6 mm; width of frontal lobe = 3·8 mm; A = 1·7 mm; width of eye crescent = 1·5 mm; A/G = 42·5%; A/Gn = 37·7%; width of occipital ring = 2·7 mm.

Remarks. The species was proposed by Salter for the small, distinctive, phacopid cephala that form an important element of the south Cornwall faunas. It has never yet been recognized elsewhere. Conspicuous changes of shape occur in these cephala during only slight deformation, but these effects can be assessed and removed. The description is based upon two cephala (Zs 608b, Zs 608c) preserved 18 mm apart, at right angles, and without visible angular shear strain. Measurement of ratios of parallel lengths does not indicate any primary differences and for these two individuals to represent L- and W-forms a strain ellipse axis ratio of only 1:0·894 is required. Such a strain is compatible with other measurements of this fauna and so the description is essentially based on an O-form reconstructed from these two (text-fig. 8).

Salter separated his new species from *Phacops apiculatus* M'Coy, 1851, on cephalic proportions and on the conspicuous lateral border furrow of the former. *K.* (*K.*) *mimus* is distinguished from *K.* (*K.*) *apiculatus* by its larger, weakly curved eyes set relatively close to the axial furrows. *K.* (*K.*) *micheli* (Tromelin, 1876), a species of

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EXPLANATION OF PLATE 10

Ogygiocaridinae gen. indet.

Fig. 1. GSM Zs 587, librigena, internal mould, Catasuent, ×1·5. Fig. 2. GSM Zs 588, incomplete pygidium, internal mould, Catasuent, ×1.

Trinucleidae gen. indet, all from Catasuent, ×3·5.

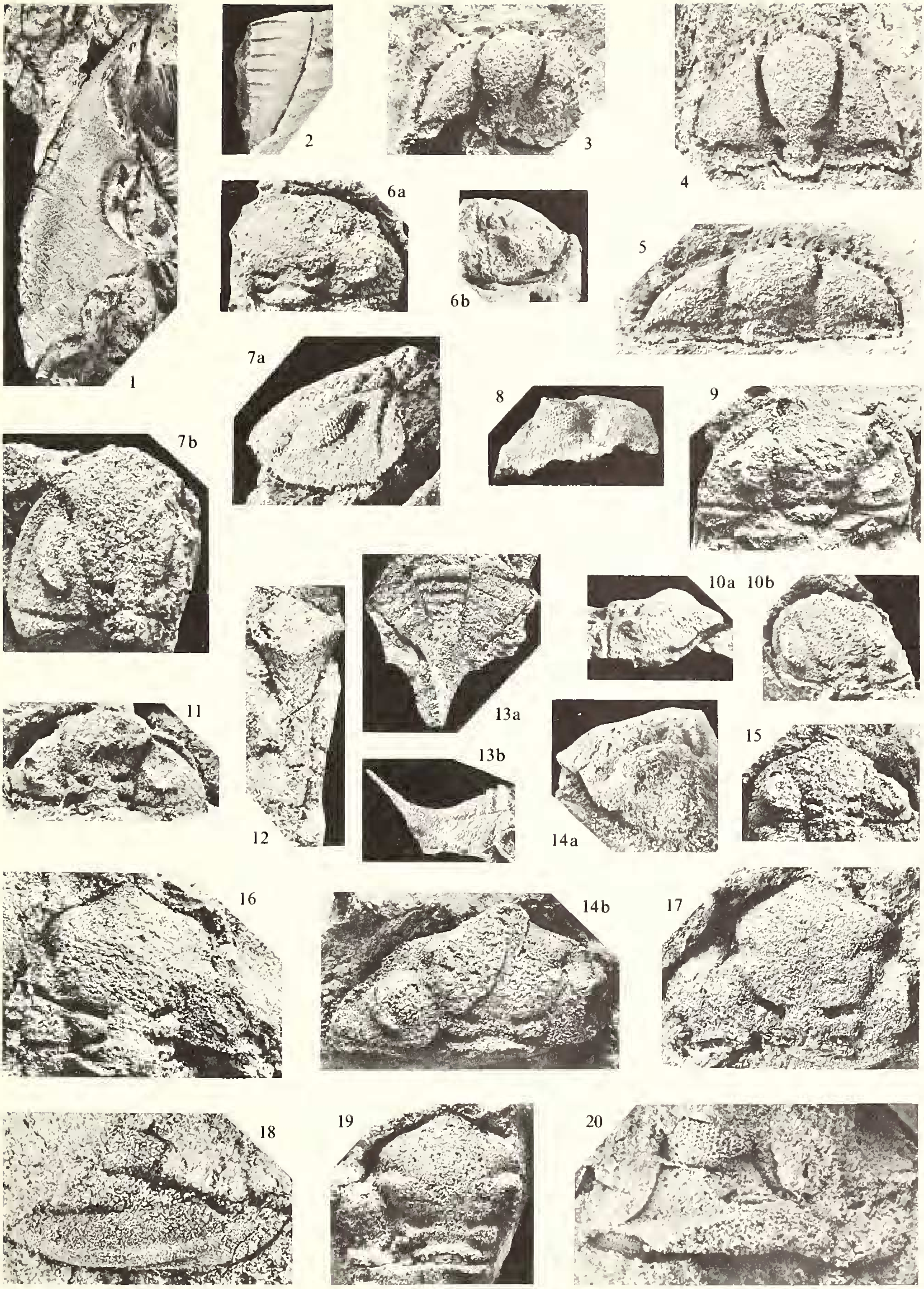
Fig. 3. GSM Zs 575, cephalon, internal mould. Fig. 4. GSM Zs 577, cephalon, internal mould, showing eye tubercles and median glabellar tubercle. Fig. 5. GSM Zs 573, cephalon, internal mould.

Kloucekia (*Kloucekia*) *mimus* (Salter).

Fig. 6*a–b*. GSM Zs 597, W-form cephalon, internal mould, Catasuent, ×3·5. Fig. 7*a–b*. GSM Zs 600, incomplete L-form cephalon, internal mould, Catasuent, ×4. Fig. 8. GSM Zs 595, incomplete W-form cephalon, internal mould, Catasuent, ×4. Fig. 9. GSM 19180, lectotype, cephalon, internal mould, Perhaver, ×3·3. Fig. 10*a–b*. GSM Zs 605a, cephalon, internal mould showing angular shear strain, Catasuent, ×4. *a*, slightly oblique.

Crozonaspis peachi n. sp., all from Carne, all ×3 except fig. 18 ×4 and fig. 20 ×3·5.

Fig. 11. GSM Zs 676, crushed cephalon, internal mould. Fig. 12. GSM Zs 658b, caudal spine, latex cast of external mould. Fig. 13*a–b*. GSM Zs 658a, paratype pygidium, latex cast of external mould. Fig. 14*a–b*. GSM Zs 677, holotype, cephalon, internal mould. Fig. 15. GSM Zs 679, immature cephalon, internal mould. Fig. 16. GSM Zs 673, cranidium, internal mould. Fig. 17. GSM Zs 674, cranidium, internal mould. Fig. 18. GSM Zs 667, paratype right librigena and eye, latex cast of external mould—counterpart of Zs 666. Fig. 19. GSM Zs 675, paratype cranidium, internal mould. Fig. 20. GSM Zs 666, paratype right librigena and eye, internal mould—counterpart of Zs 667.



SADLER, Cornish Ordovician trilobites

Llandeilo age and close to the type-species, was established on the basis of its much larger eyes (Henry 1965, p. 205), which are slightly larger and taller than the Cornish species. The glabella of *K.* (*K.*) *micheli* is more convex and relatively wide anteriorly, resembling more the supposed W-forms of *K.* (*K.*) *mimus*. The two species are very similar and both occasionally carry fixigenal spines (Henry 1965, p. 202). The glabellar profile resembles *Phacopidella*, but that genus is distinguishable by its large eyes set close to the posterior margin and by its axial furrows, which diverge forward at 45–55° (Nion and Henry 1966, p. 889). The genus *Baniaspis* Destombes has much smaller eyes.

Subfamily DALMANITININAE Destombes, 1972

Struve (1958, p. 190) distinguished a *Dalmanitina* group within the subfamily Zeliszkellinae (Delo 1935) on the basis of a well-developed lateral border and border furrow which are constricted or completely suppressed anteriorly by the frontal lobe of a club-shaped glabella, on the relatively small eyes situated away from the antero-lateral border, on the presence of genal spines and on a mucronate pygidium with relatively numerous segments. Destombes (1972, p. 36) elevated the group to the status of a separate subfamily. His diagnosis for the subfamily Zeliszkellinae is a straight translation of Struve's diagnosis of the *Zeliszkella* group. His diagnosis for the subfamily Dalmanitininae is clearly based on Struve's proposals for the *Dalmanitina* group, but with the presence of three, generally equally incised glabellar furrows as an added specification.

Genus CROZONASPIS Henry, 1968

Type-species. Crozonaspis struvei Henry, 1968, by original designation.

Diagnosis. (After Henry 1968, p. 368.) A genus characterized by an ogival cephalon with a very narrow anterior border, which is enlarged as a short rounded 'beak' (as a term to describe this projection of the anterior border, Henry's word 'rostre', 1968, p. 368, cannot be directly rendered into English in accordance with the Treatise definitions) at the median line. 1p glabellar furrows wide (exsag.) and deep; 2p furrows and 3p furrows weakly defined. Eyes oblique to axial furrows so that palpebral area increases rapidly in width posteriorly. Pygidium with large caudal spine and with few pleura in lateral lobes.

Remarks. Henry (1968, p. 369) considered his new genus to be very close to *Dalmanitina*, and set out the means of distinguishing it from the several *Dalmanitina* subgenera, as well as the case for establishing it at generic level. The resemblances to *Dalmanitina* include reduced anterior border, relatively small eyes, genal spines, bifurcation of internal extremities of 1p lateral glabellar furrows, convergence of 1p and 2p furrows and the mucronate pygidium. These features support the placing of *Crozonaspis* in the Dalmanitininae. However, the points of difference—relatively weak 2p and 3p glabellar furrows, and the relatively small number of pygidial pleurae, with weak interpleural furrows—introduce features of the Zeliszkellinae, especially if Destombes's addition of glabellar segmentation to the diagnosis of the Dalmanitininae is accepted. The establishment of *Cr. chouberti* Destombes adds relatively large eyes, another zeliszkellinid feature, to the scope of the genus.

Distribution. The four species already known are all of Llandeilo age. *Cr. struvei* Henry and *Cr. kerfornei* Clarkson and Henry are known from Brittany, *Cr. chouberti* Destombes from Morocco, and *Cr. incerta* (Deslongchamps) from Normandy and Spain.

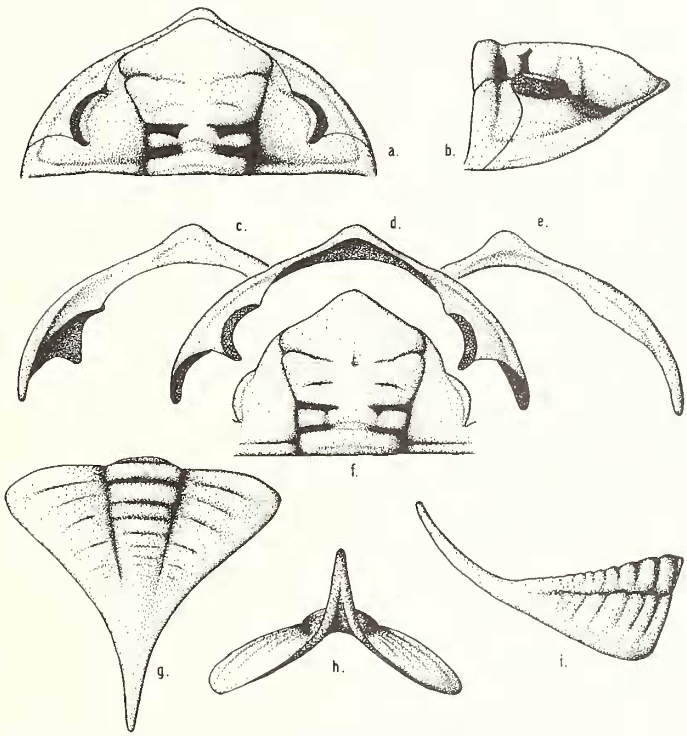
Crozonaspis peachi n. sp.

Plate 10, figs. 11–20; text-fig. 9

Derivatio nominis. In tribute to C. W. Peach, who first collected trilobites in south Cornwall and mapped the distribution of the fossiliferous quartzites.

Holotype. Cephalon, GSM Zs 677, Carne Beach, author's collection (Pl. 10, figs. 14*a–b*). *Paratypes.* GSM Zs 675, cranidium, Pl. 10, fig. 19; GSM Zs 677b, 671a, 671b, cranidia; GSM Zs 667, 666, librigenae, Pl. 10, figs. 18 and 20; GSM Zs 661, 662, librigenae with anterior border; GSM Zs 658a, pygidium, Pl. 10, figs. 13*a–b*. *Locus typicus.* Carne Beach, Veryan, South Cornwall (SW 9109 3793). *Stratum typicum.* Gorran Quartzites, Ordovician (?Llandeilo). *Material.* Carne Beach—4 cephala, 22 cranidia, 18 librigenae, 27 pygidia, 1 caudal spine.

Diagnosis. A species of *Crozonaspis* characterized by a relatively wide cephalon (tr.) and moderately large eyes set away from the glabella posteriorly and not interrupting the lateral border furrow in plan view. 3p glabellar furrows deepen distally and connect with axial furrows.



TEXT-FIG. 9. Reconstruction of *Crozonaspis peachi* n. sp. *a–b*, cephalon (internal mould); *c–e*, librigenae: *c*, external cast (ventral), *d*, external cast (dorsal), *e*, internal mould (ventral); *f*, cranidium, external cast (dorsal); *g–i*, pygidium (external cast): *g*, dorsal, *h*, posterior, *i*, right lateral view. *a–f* $\times 3$; *g–i* $\times 4$.

Description. Cephalon ogival in outline, almost half as long as maximum width (measured across occipital furrow). Glabella pentagonal, pointed anteriorly. Axial furrows moderately deep, becoming shallower anteriorly, diverging forward at about 40–45° in front of 1p glabellar lobes. Three paired glabellar lobes and furrows. 1p glabellar furrows short, straight, directed slightly backward adaxially and very deep, each about one-third glabellar width. Internal extremities bifurcate, anterior branch deeper, directed toward axis, posterior branch (more deeply incised in external casts than internal moulds) directed toward occipital furrow, tending to isolate 1p lobes. 2p furrows least well marked (especially on internal moulds), short, slightly convex forward, directed slightly forward adaxially, shallowing abaxially, not connected with axial furrows. 3p furrows distinct, but shallow adaxially, long, sinuous, directed backward adaxially. They comprise two shallow flat arcs, each convex forward, abaxial arc deepest, shallow where connected to axial furrows. 2p and 3p furrows usually visible on internal moulds and always distinct on the very fragmentary external moulds (text-figs. 9*a* and *f*). 1p glabellar lobes narrow (exsag.) adaxially tending toward isolation from median area. 2p lobes narrow (exsag.) adaxially. 3p lobes narrow adaxially, anterolateral portions may become markedly convex. Frontal glabellar lobe lozenge-shaped, twice as wide (tr.) as long. Glabellar profile (sag.) high, convex, descending steeply to anterior border. Occipital ring slightly higher than glabella. Occipital furrow convex forward, well-marked medially, very deep laterally. Anterior areas of fixigenae very small. Palpebral areas large, convex, widest posteriorly. Posterior areas wide (tr.), deep posterior border furrow, genal angles not seen. Eyes moderately large, crescentic, extending from 3p lobe to occipital furrow, diverging from axial furrows backward. Major ocular index (Struve 1958, pp. 167–168), A/G, 42–45%; minor ocular index, A/Gn, 35–38%. Visual surface schizochroal, at least twenty-four dorso-ventral files, bearing up to seven lenses. In plan view, eyes do not interrupt anterolateral border furrows. Facial suture proparian. Anterior portion of suture closely follows anterior margin of glabella. Anterior border very narrow, swelling slightly at median line (these features are usually damaged on whole cephala but can be seen in disarticulated librigenae). This projection of the anterior border, or 'beak', corresponds to a distinct, rounded ventral bulge in the wide anterior cephalic doublure. Main portion of librigenae (below eyes) steeply inclined to horizontal (60–70°). Pronounced anterolateral border furrow and wide border at 45° to horizontal. Librigenae have a wide anterolateral doublure bearing a deep, oblique furrow. Small, immature cephala (Pl. 10, fig. 15) have relatively large eyes. Major ocular index, 55%; minor ocular index, 50%. Hypostoma and original shell surface not known. Large, triangular pygidium. Axis stands high anteriorly between distinct axial furrows, but becomes poorly defined backward of mid length. Seven to eight distinct axial rings behind articulating half-ring, becoming smaller backward. Posterior portion of axis comprises an unsegmented, poorly defined ridge, continuing as a long, caudal spine, upturned as much as 60° from horizontal. Stout anterior end of spine bears a deep ventral furrow. Pleural lobes are set at 110–140° to one another and bear up to five pairs of furrows.

Dimensions. Holotype cephalon: length of glabella (sag.), including occipital ring (Gn) = 7·8 mm; length of glabella without occipital ring (G) = 6·6 mm; length of frontal lobe = 3·3 mm; width of frontal lobe (tr.) = 7·5 mm; distance between eye and posterior border furrow = 0·9 mm; length of eye (A) = 3·0 mm; A/G = 45·4%; A/Gn = 38·7%; width of occipital ring = 4·7 mm; width (tr.) of fixigena (max.) = 5·4 mm.

Paratype pygidium: width of anterior axial lobe = 3·0 mm; maximum width of pleural lobe = 3·7 mm; length of axis including caudal spine = 9·0+ mm.

Remarks. Compared with the four other species, *Crozonaspis peachi* has a relatively short, wide cephalon. It more closely resembles *Cr. chouberti* Destombes and *Cr. incerta* (Deslongchamps) than it does the Brittany species, which have distinctly smaller eyes. *Cr. struvei* Henry: A/G = 27–28%, A/Gn = 23%; *Cr. kerfornei* Clarkson and Henry: A/G = 32%, A/Gn = 28%. The eyes of these species are correspondingly farther from the posterior border furrow. The eyes of *Cr. chouberti* (A/G = 50–61%, A/Gn = 42–52%) are larger than those of *Cr. peachi*. In both species the posterior extremities of the eyes lie immediately forward of the occipital furrow, but in *Cr. chouberti* the eyes continue as far forward as the 3p glabellar furrows. In the latter species the eyes are taller and set closer to the anterolateral border furrows, which they interrupt in plan view. The 3p glabellar furrows in *Cr. peachi* may become very shallow adjacent to the axial furrows, but do not show the interruption that is characteristic of the Brittany species. In this respect *Cr. peachi* again resembles more the Normandy species and the Moroccan species. *Cr. incerta* most closely resembles the new species, but has a relatively narrow cephalon. The eyes of *Cr. incerta* are probably relatively small (A/G approx. 37–38%; A/Gn approx. 31–32%) compared with *Cr. peachi*, but they have not been satisfactorily illustrated. *Cr. peachi* is most readily distinguished by its 2p and 3p furrows which are typically distinctly marked, especially 3p and on external moulds. On certain internal moulds (Pl. 10, fig. 16) traces of 2p and 3p furrows are imperceptible, resembling the condition in *Cr. incerta*.

Acknowledgements. This work was undertaken during a research assistantship at the University of Bristol, financed by N.E.R.C. and supervised by Dr. S. C. Matthews, who was a source of vital encouragement and advice during preparation of the paper. Valuable criticisms of an early draft were kindly given by Professor H. B. Whittington, F.R.S., and by Dr. A. W. A. Rushton, who also, on behalf of the Institute of Geological Sciences, generously made available material from earlier collections. For the photographs I am indebted to the expertise of Mr. E. W. Seavill.

REFERENCES

BARRANDE, J. 1872. Système silurien du centre de la Bohême. I (*Supplement*) *Trilobites, Crustacés divers + Poissons*. Prague–Paris, 647 pp., 37 pls.

BATES, D. E. B. 1968. The Lower Palaeozoic brachiopod and trilobite faunas of Anglesey. *Bull. Br. Mus. nat. Hist.* (Geol.) **16,** 125–199, pls. 1–9.

—— 1969. Some early Arenig brachiopods and trilobites from Wales. Ibid. **18,** 1–28, pls. 1–9.

BORN, A. 1916. Die *Calymene Tristani* Stufe (mittleres Unter Silur) bei Almaden und ihre Fauna, Gliederung und Verbreitung. *Abh. senckenb. naturforsch. Ges.* **36,** 309–358, pls. 24–27.

—— 1953. El tramo de *Calymene tristani* en Almadén (Ordoviciense medio) su fauna, división y extensión (transl. B. Melendez from Born 1916). *Publ. extranjeros geol. Esp.* **7,** 175–263, pls. XIII–XVIII.

BRONGNIART, A. 1822. *Histoire naturelle des Crustacés fossiles: Les trilobites*. Paris, 154 pp., 11 pls.

CARRÉ, D., HENRY, J.-L., POUPON, G. and TAMAIN, G. 1972. Les Quartzites Botella et leur faune trilobitique. Le problème de la limite Llandeilien-Caradocien en Sierra Morena. *Bull. Soc. géol. Fr.* (7), **12,** 774–785, pl. XXV.

CHAUVEL, J., DROT, J., PILLET, J. and TAMAIN, G. 1969. Précisions sur l'Ordovicien moyen et superieur de la 'série-type' du Centillo (Sierra Morena orientale, Espagne.). Ibid. (7), **11,** 613–626, pls. XIII–XV.

CLARKSON, E. N. K. 1966. Schizocroal eyes and vision of some Silurian acastid trilobites. *Palaeontology*, **9,** 1–29, pls. 1–3.

—— and HENRY, J.-L. 1970. Sur une nouvelle éspèce du genre *Crozonaspis* (Trilobite) découverte dans l'Ordovicien de la Mayenne. *Bull. Soc. géol. Fr.* (7), **11,** 116–123.

COLLINS, J. H. 1893. A working list of the Palaeozoic fossils of Cornwall. *Trans. R. geol. Soc. Corn.* **11,** 421–479.

DEAN, W. T. 1960–1. The Ordovician trilobite faunas of South Shropshire (2 parts). *Bull. Br. Mus. nat. Hist.* (Geol.) **4,** 73–143, 313–358, pls. 11–19, 49–55.

—— 1964. The status of the Ordovician trilobite genera *Prionocheilus* and *Polyeres*. *Geol. Mag.* **101,** 95–6.

—— 1965. A revision of the Ordovician trilobite genus *Bathycheilus* Holub. *Sb. nár. Mus. Praze.* **21B,** 1–10, pls. 1–2.

—— 1966. The Lower Ordovician stratigraphy and trilobites of the Landeyran Valley and the neighbouring district of the Montagne Noire, south-western France. *Bull. Br. Mus. nat. Hist.* (Geol.) **12,** 245–353, pls. 1–21.

—— 1967. The correlation and trilobite fauna of the Bedinan Formation (Ordovician) in south-eastern Turkey. Ibid. **15,** 81–123, pls. 1–10.

—— 1971. The Lower Palaeozoic stratigraphy and faunas of the Taurus Mountains near Beysehir, Turkey. II. The Trilobites of the Seydisehir formation (Ordovician). Ibid. **20,** 1–24, pls. 1–5.

DELO, D. M. 1935. A revision of the phacopid trilobites. *J. Paleont.* **9,** 402–420.

DESTOMBES, J. 1972. Les Trilobites du sous-ordre des Phacopina de l'Ordovicien de l'Anti-Atlas (Maroc). *Notes Mém. Serv. Mines Carte géol. Maroc*, **240,** 5–112, pls. 1–16.

FOX, H. 1908. Trilobite in the Veryan Quartzite. (Note on a specimen of *Calymene* from Veryan by P. Lake.) *Trans. R. geol. Soc. Corn.* **13,** 233–236.

GIGOUT, M. 1951. Études géologiques sur la Meseta marocaine occidentale (arrière pays de Casablanca, Mazagan et Safi). *Notes Mém. Serv. Mines Carte géol. Maroc*, **86,** 1–507, pls. 1–18.

HARRINGTON, H. J. and LEANZA, A. F. 1957. Ordovician trilobites of Argentina. *Spec. Publs. Univ. Kansas Dept. Geol.* **1,** 267 pp.

HENNINGSMOEN, G. 1960. The Middle Ordovician of the Oslo region 13. Trilobites of the family Asaphidae. *Norsk. geol. Tidsskr.* **40,** 203–257.

HENRY, J.-L. 1965. Révision de *Kloucekia micheli* (Tromelin 1876) (Trilobite, Ordovicien Moyen du massif armoricain). *Bull. Soc. géol. minér. Bretagne* (March 1965), 199–210, pl. I.

—— 1968. *Crozonaspis struvei* n.g., n.sp., Zeliszkellinae (Trilobita), de l'Ordovicien moyen de Bretagne. *Senckenberg. leth.* **49,** 367–380, pls. 1–2.

—— 1970. Quelques Calymenacea (Trilobites) de l'Ordovicien de Bretagne. *Annls. Paléont.* (Invert.) **56,** 3–27, pls. A–C.

HICKS, H. 1872. On the Tremadoc rocks in the neighbourhood of St. David's, South Wales, and their fossil contents. *Q. Jl geol. Soc. Lond.* **29,** 39–52, pls. 3–5.

HOLUB, K. 1908. Přisoĕvek ku poznáni fauny pásma Ddiγ. *Rozpr. české Akad.* **17,** 1–19, pl. 1.

KOBAYASHI, T. 1951. On the Ordovician trilobites in Central China. *J. Fac. Sci. Univ. Tokyo*, **8,** 1–87, pls. I–V.

LU, H. Y. 1957. *Trilobita. In Index Fossils of China, Invertebrate*, **3,** 249–294, pls. 137–155. [In Chinese.]

MOORE, R. C. 1959. *Treatise on invertebrate paleontology. Part O. Arthropoda I.* 579 pp. Kansas.

MURCHISON, R. I. 1846. A brief review of the classification of the sedimentary rocks of Cornwall. *Trans. R. geol. Soc. Corn.* **6,** 317–326.

NION, J. and HENRY, J.-L. 1966. *Phacopidella* (*Prephacopidella*) *hupei* sp. nov.—nouveau trilobite de l'Ordovocien du Finistère. *Bull. Soc. géol. Fr.* (7), **8,** 884–890, pl. XXIV.

OEHLERT, D. P. 1895. Sur les *Trinucleus* de la France. Ibid. (3), **23,** 299–336.

PEACH, C. W. 1841. An account of fossil organic remains found on the south-east coast of Cornwall. *Trans. R. geol. Soc. Corn.* **6,** 12–23.

—— 1842. On the geology of part of the parish of Gorran in Cornwall. Ibid. **6,** 51–58.

—— 1844. On the fossil geology of Cornwall. Ibid. **6,** 181–185.

POMPECKJ, J. F. 1898. Über *Calymene* Brongniart. *Neues Jb. Miner. Geol. Paläont.* **1,** 186–250.

REED, F. R. C. 1915. Supplementary memoir on new Ordovician and Silurian fossils from the northern Shan States. *Mem. geol. Surv. India*, **4,** 102 pp., 12 pls.

REID, C. 1907. Geology of the country around Mevagissey. *Mem. geol. Surv. U.K.* 353 and 354.

RENAUD, A. 1952. Les Collections paléontologiques du Musée vieux Chateau de Laval. *Bull. Mayenne-Sci.* 29–60, pls. I–IV.

—— PONCET, J., CAVET, P., LARDEUX, H. and BABIN, C. 1968. Le Devonien du Massif Armoricain. In *International symposium on the Devonian system.* D. H. Oswald (ed.), Calgary, **1,** 135–152.

RICHTER, R. 1948. *Einfuhrung in die Zoologische Nomenclatur.* Kramer, Frankfurt-a.-M., 252 pp. (2nd edn.).

—— and RICHTER, E. 1949. Die Trilobiten der Erdbach-Zone (Kulm) im Rheinischen Schiefergebirge und im Harz. *Senckenbergiana* **30,** 63–94, pls. 1–3.

ROUAULT, M. 1847. Extrait de mémoire sur les trilobites du département d'Ille-et-Vilaine. *Bull. Soc. geol. Fr.* (2), **4,** 309–328, pl. III.

SALTER, J. W. 1864*a*. Note on the fossils from the Budleigh Salterton Pebble-Bed. *Q. Jl geol. Soc. Lond.* **20,** 286–302.

—— 1864–83. A monograph on the British trilobites from the Cambrian, Silurian and Devonian. *Palaeontogr. Soc.* [*Monogr.*], 5 Parts.

SDZUY, K. 1957. Bemerkungen zur Familie Homalonotidae (mit der Beschreibung einer neuen Art von *Calymenella*). *Senckenberg. leth.* **38,** 275–290, pl. 1.

SEDGWICK, A. 1852. On the slate rocks of Devon and Cornwall. *Q. Jl geol. Soc. Lond.* **8,** 1–19.

SHIRLEY, J. 1936. Some British trilobites of the family Calymenidae. Ibid. **92,** 384–422, pls. XXIX–XXXI.

SIEGFRIED, P. 1969. Trilobiten aus dem Ordovizium des Ebbe-Sattels im Rheinischen Schiefergebirge. *Paläont. Z.* **43,** 148–168.

SPJELDNAES, N. 1961. Ordovician climatic zones. *Norsk. geol. Tidsskr.* **41,** 45–77.

STRUVE, W. 1958. Beiträge zur Kenntnis der Phacopacea (Trilobita), I. Die Zeliszkellinae. *Senckenberg. leth.* **39,** 165–219, pls. 1–4.

STUBBLEFIELD, C. J. 1939*a*. Some Devonian and supposed Ordovician fossils from south-west Cornwall. *Bull. geol. Surv. Gt. Brit.* **2,** 63–71.

—— 1939*b*. Some aspects of the distribution and migration of trilobites in the British Lower Palaeozoic faunas. *Geol. Mag.* **74,** 49–72.

—— 1960. Trilobites of south-west England. *Trans. R. geol. Soc. Corn.* **19,** 101–112.

THADEU, D. 1956. Note sur le Silurien biero-durien. *Bolm. Soc. geol. Port.* **12,** 1–42, pls. I–X.

TRISTAN, J. and BIGOT, P. S. M. 1808. Notice sur les crustacés renfermés dans quelques schistes notamment dans ceux des environs de Nantes et d'Angers. *J. Mines*, **23,** 21–32.

VOGDES, A. W. 1925. Palaeozoic Crustacea. *Trans. S. Diego Soc. nat. Hist.* **4,** 1–154.

WARRINGTON, G. 1971. Palynology of the New Red Sandstone sequence of the south Devon coast. *Proc. Ussher Soc.* **2,** 307–314.

WELLMAN, H. W. 1962. A graphical method for analysing fossil distortion caused by tectonic deformation. *Geol. Mag.* **99,** 348–352.

WHITTARD, W. F. 1955–67. The Ordovician trilobites of the Shelve inlier, west Shropshire. 9 Parts. *Palaeontogr. Soc.* [*Monogr.*], 352 pp., pls. I–L.

WHITTINGTON, H. B. 1962. The Ordovician trilobites of the Bala area, Merioneth. Part I. Ibid. 1–32, pls. I–XXXII.

—— 1966*a*. Trilobites of the Henllan Ash, Arenig Series, Merioneth. *Bull. Br. Mus. nat. Hist.* (Geol.) **11,** 491–505, pls. 1–5.

—— 1966*b*. Phylogeny and distribution of Ordovician trilobites (Presidential Address). *J. Paleont.* **40,** 696–737.

—— 1968. *Cryptolithus* (Trilobita): specific characters and occurrences in Ordovician of North America. Ibid. **42,** 702–714, pls. 87–89.

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Revised typescript received 15 February 1973